

Received: 03 July 2024 • Revised: 10 October 2024 • Accepted: 28 November 2024

Research

doi: 10.22034/jcema.2024.217203

Evaluation of Traffic Parameters in the Presence of Traffic Speed Bumps on Urban Routes

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ABSTRACT

If the driver exceeds the posted speed, the speed bump causes a gentle jolt to the car. In a situation where the car crosses the speed bump at a dangerous speed, the barrier causes a severe jolt to the car, which can cause discomfort to the passengers and even break the vehicle's cargo. The study of traffic flow parameters can express the results of installing traffic calming devices so that they can help reduce the speed of vehicles. Following the speed reduction, street safety increases and the number and severity of accidents are reduced. In this study, important traffic diagrams are drawn, including flow-density, speed-density, speed-flow, and delay-flow time, so that by studying and analyzing these diagrams, the relationship between traffic parameters in different scenarios and under different distances between speed bumps can be found and a more accurate analysis can be provided in relation to different scenarios. The results showed that the greater the flow volume, the lower the speed, but if in the current situation, we reduce the distance between the speed straws, we reach the maximum flow volume at a lower speed. With increasing density, the speed of vehicles decreases, but in the current situation, if we reduce the distance between the speed straws, we reach the maximum density at a lower speed.

Keywords: Traffic straw speed, traffic flow parameters, traffic modeling, Aimsun software

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1. INTRODUCTION

The idea of traffic calming was first proposed by experts from a number of European countries, especially the Netherlands and Germany, in the early 1970s. Traffic calming is a set of measures that were initially carried out only in developed countries, but today it is being considered in most countries of the world. Traffic calming has two main goals: reducing the number and severity of accidents and increasing the desirability of the urban and suburban environment. [1] These goals lead to a reduction in some parameters, including the volume of traffic passing through the route and the speed of

vehicles, and consequently the capacity of the route. In many cases, we witness the construction and implementation of speed bumps or other calming measures on city streets that practically do not justify the main purpose of these plans and are ineffective in reducing the speed and volume of traffic or make the situation worse than the current situation [2-4]. For example, implementing two speed bumps in a row and with a distance less than the desired amount will cause both of them to act like one speed bump, which means wasting money and energy. If Tehran Municipality has a suitable model, it can decide

which street should be calmed and, if the plan is implemented, what should be the distance between the calming devices and their type according to the conditions of the desired street [5].

Speed bumps are used to reduce speed in car parking lots, shopping malls, and similar areas within the city. Their height is between 7 and 10 centimeters and their length is maximum 30 centimeters, and they are installed across the road. A speed bump is a device that is between 7- and 10-centimeters height and its length is maximum 3.5 to 4.5 meters, and it is installed across the road. The length of the speed bump may reach 6.7 meters, in such cases it is also called a Speed Table. A speed bump warning sign is installed 200 or 150 meters before the speed bump. Experience has shown that using phosphorescent signs with additional signs indicating the distance to the speed bump is much more effective than installing conventional speed bump warning signs [6-8]. Speed bumps play an effective and significant role in reducing high speeds and can minimize many dangerous accidents by installing them in sensitive areas such as schools and hospitals. Paying attention to speed bump standards in urban and suburban roads, stop and check points, high-slope roads, hospitals and clinics, educational centers, shopping centers, residential areas, etc. significantly reduces vehicle speeds and ensures the safety of pedestrians and vehicle occupants. Each type of speed bump has different characteristics, which are used accordingly. For example, asphalt and rubber speed bumps are more commonly used in tropical areas, or high-height speed bumps are not used in areas where bicycles and motorcycles are used [9].

1.1. Plastic speed bumps

This type of traffic equipment has high durability and longevity in environmental conditions and due to its structure, it can be adapted to any weather conditions and does not wear out. The plastic speed bump is made of resistant polymers and reduces the high speed of machines and vehicles as they pass, repels negative impacts and does not damage the vehicle. The reflective and warning color of the plastic speed bump is an excellent guide for drivers at night. This type of speed bump is cheaper than the rubber type and is mainly used in environments with moderate weather and urban roads [10].

1.2. Asphalt and concrete speed bumps

The material that makes up this type of traffic equipment is concrete, asphalt and stone, and for this reason, its installation can be done permanently, does

not require repairs after installation and can be highly resistant and durable against the passage of very heavy machinery. Al-Shater (2012) introduces traffic calming as a way to address the impacts of cars on urban centres and residential areas, and among his goals of calming is reducing traffic volume and reducing vehicle speeds [11]. According to a group of Australian experts, many of the seemingly different definitions of traffic calming are similar, and Brindle (1992) accordingly divides calming into three levels: [12]

1. Operations limited to local (residential) levels to control traffic speeds and reduce their impacts;
2. Operations extended to the mesoscale level; and
3. Operations at the macroscale level to reduce traffic levels and their impacts at the city level.

Level three brings the discussion of traffic calming into the realm of urban transport policy, while level one focuses on the most common form of calming operations, known in Australia as “local area traffic management”. This separation of levels is just one interpretation of the broader and narrower definitions of traffic calming. Haas-Klau (2001) has stated that traffic calming is “purely a traffic engineering approach and not a part of urban improvement management” [13]. The concepts and techniques of calming have been developed based on theoretical and practical considerations, and according to Collins (2004), “traffic calming uses a variety of methods, from simple traffic management to comprehensive highway improvements and reconstructions.” Although there are different interpretations of what traffic calming is, according to Collins, “there is a clear concept of what it is not. Traffic calming is not about eliminating unnecessary and irrelevant traffic, but about managing traffic behavior, because unnecessary traffic cannot be eliminated.” [14-18]

Speed bumps are raised circular surfaces installed perpendicular to the roadway. They are usually 3 to 4 m long (in the direction of travel) and have an effective height of 7.5 to 10 cm. They reduce the operational speed by 8 to 13.5 km/h and reduce the average speed by 21% to 23%. [19-21] Harrison (2002) confirms that speed bumps of any type have the greatest effect on reducing speeds on residential and community streets. According to Farrow (1989), “speed reduction is a key criterion for evaluating traffic calming schemes.” Ewing (1999), Hallmark

(2002) and Zach (2009) found an operational speed reduction of about 18% in calmed areas, based on their before and after studies of speed bumps and speed bumps. In different locations, the average

speed has been reduced by between 6 and 13 km/h [22-27]. Mr. Alfredo and his colleagues in 2011 investigated the effects of traffic calming devices on road capacity density [28].

2. MATERIALS AND METHODS

2.1. Case Study

The study area is one of the streets calmed by speed bumps in Tehran, the specifications of which are given in Table (1). In this section, the simulated computer model of Shahr-Ara Street was calibrated in the IMSON 7.1 software [29]. This model includes a number of speed bumps as a calming device, with different distances. When examining the outputs of

the constructed models, important traffic diagrams, including Green Shields diagrams, will be drawn, and parameters such as flow, speed, delay time, and density will be examined. Then, a comparison will be made between the drawn diagrams so that the effect of the distances between the speed bumps can be directly observed.

Table 1. Physical characteristics of Shahrara Street

SPEED BUMP WIDTH (METERS)	WIDTH OF CROSSING LINES (METERS)	NUMBER OF CROSSING LINES	DISTANCE BETWEEN THE SECOND AND THIRD SPEED BUMPS (METERS)	DISTANCE BETWEEN THE FIRST AND SECOND SPEED REDUCER (M)	STREET LENGTH (METERS)
4	3	3	287	222	644

2.2. Methodology

In this section, important traffic diagrams are drawn, including flow-density, speed-density, speed-flow, and delay-flow time, so that by studying and analyzing these diagrams, the relationship between

traffic parameters in different scenarios and under different distances between speed bumps can be found and a more detailed analysis can be provided in relation to different scenarios.

3. RESULTS AND DISCUSSION

3.1. Traffic diagrams for the 400-meter scenario

In Figure (1), it can be seen that as the flow in the model increases, the speed of the vehicles begins to decrease, which continues until qmax is reached, and from this point on, the diagram, like the Greenshields

velocity-flow diagram, moves in a direction where the flow decreases and the speed approaches zero, which practically creates a standstill for all vehicles on the route.

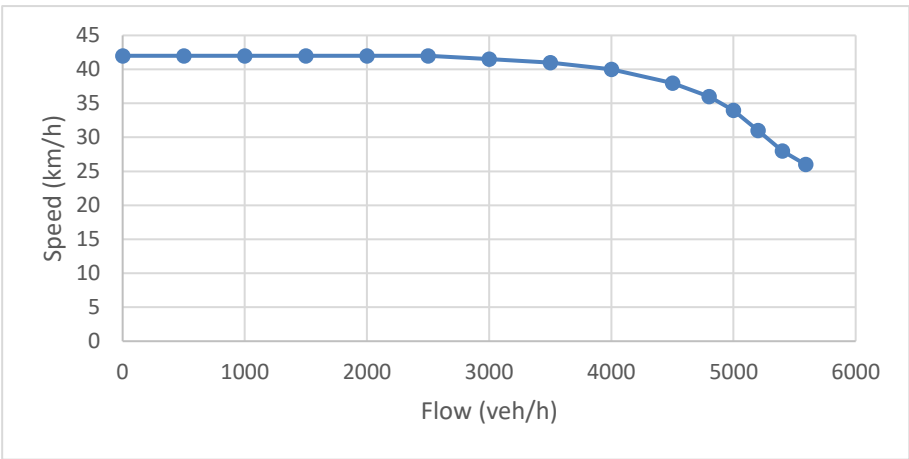


Figure 1. Speed-flow diagram for a scenario with a speed bump distance of 400 meters

Figure (2) shows the changes in vehicle speed against the density of the route, as can be seen from

the graph, as the density of the route and the density of vehicles on the route increase, their speed also

decreases. This graph is more similar to the Greenberg diagram, which is the logarithmic model of the Greenshields diagram. In this study, the modeling has been carried out until the route reaches

its capacity limit. It is natural that if more demand is imposed on the route, it will cause the density to increase and the speed of the vehicles to reach zero, in which case Kjam can be found.

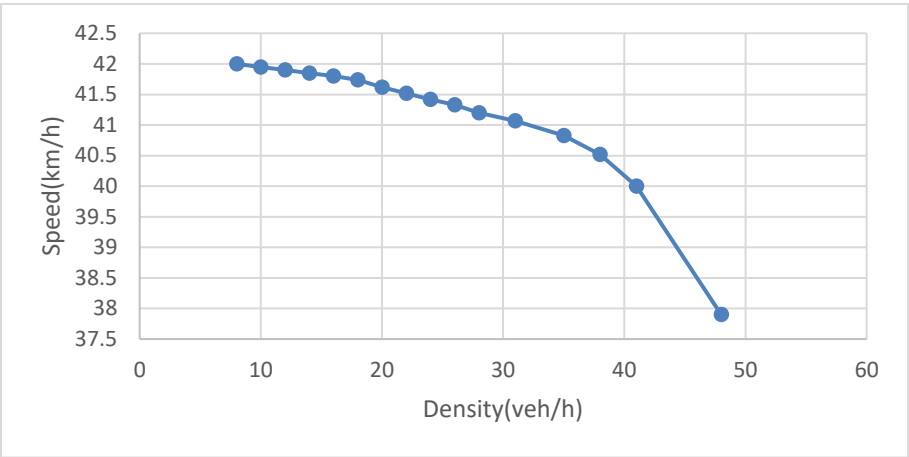


Figure 2. Linear Analysis of EC and TDS for Drain Water.

Figure (3) is the flow-density relationship that has been simulated in this study up to its peak, which is the maximum flow (Qmax) of the path.

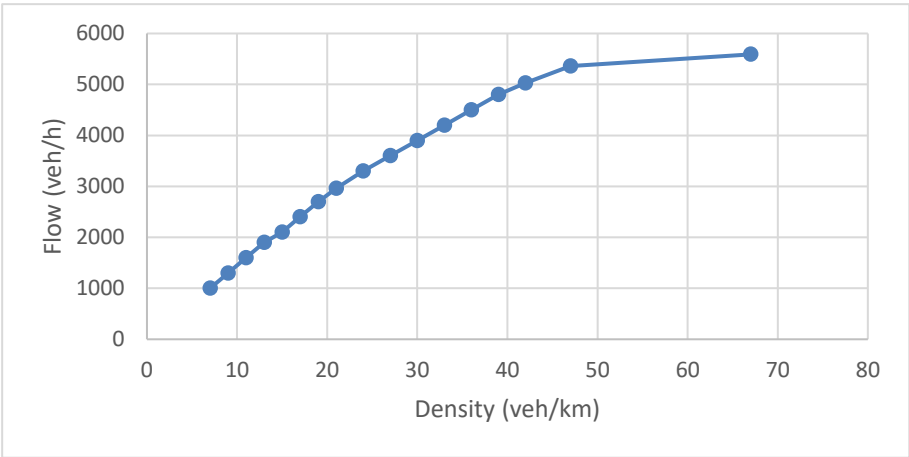


Figure 3. Linear Analysis of EC and TDS for Drain Water

Next, Figure (4) shows the changes in the delay time parameter against the current. By carefully looking at this graph, it can be seen that from a current value

where the model starts to provide capacity, the current remains constant and the delay time increases.

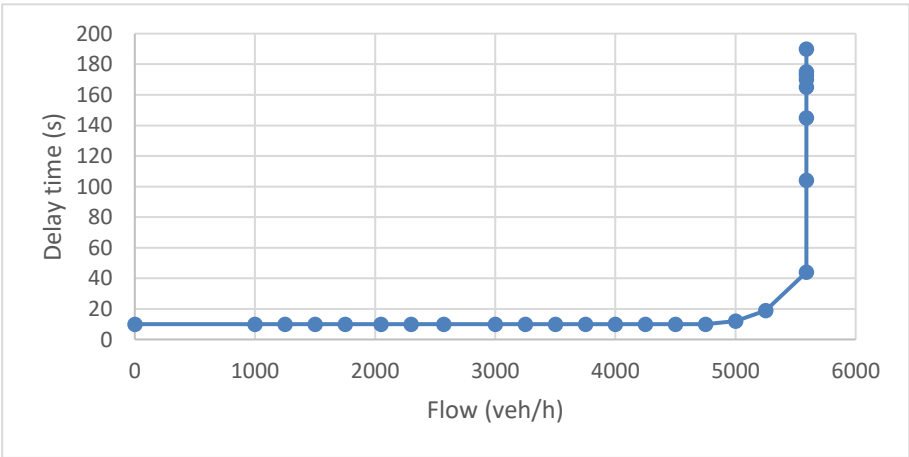


Figure 4. Linear regression Analysis of EC and TDS for Surface Water.

3.2. Traffic diagrams for the 200-meter scenario

Four traffic diagrams drawn for the 400-meter scenario are also given below for the 200-meter scenario, and naturally their pattern is similar to the diagrams for the 400-meter scenario. As can be seen

from [Figure \(5\)](#), as the traffic volume of the model increases, the density of the route reaches its maximum value (Kjam) and the speed will decrease to zero.

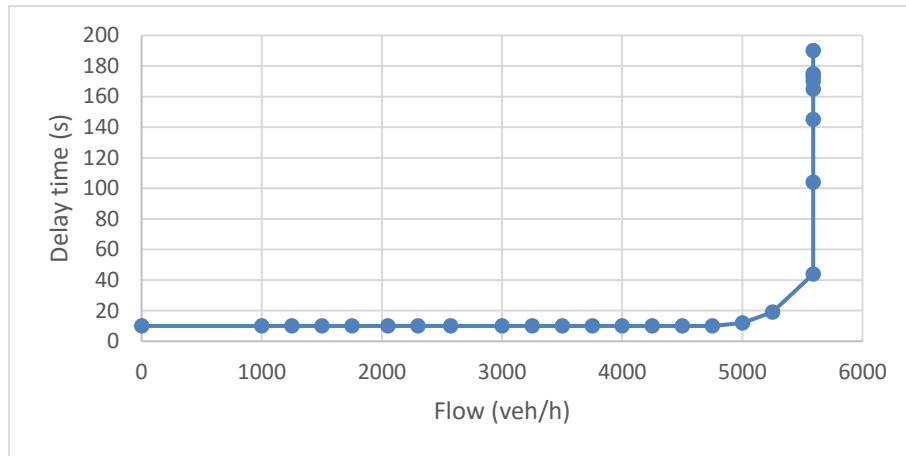


Figure 5. Speed-density diagram for the straw speed distance scenario of 200 meters

The maximum flow rate for the 200-meter scenario, as shown in [Figure \(6\)](#), is 5560 veh/h. The velocity-flow diagram is drawn to its peak, which is the

maximum volume flow rate. As demand increases in the model, the volume flow rate and vehicle speed will decrease to zero.

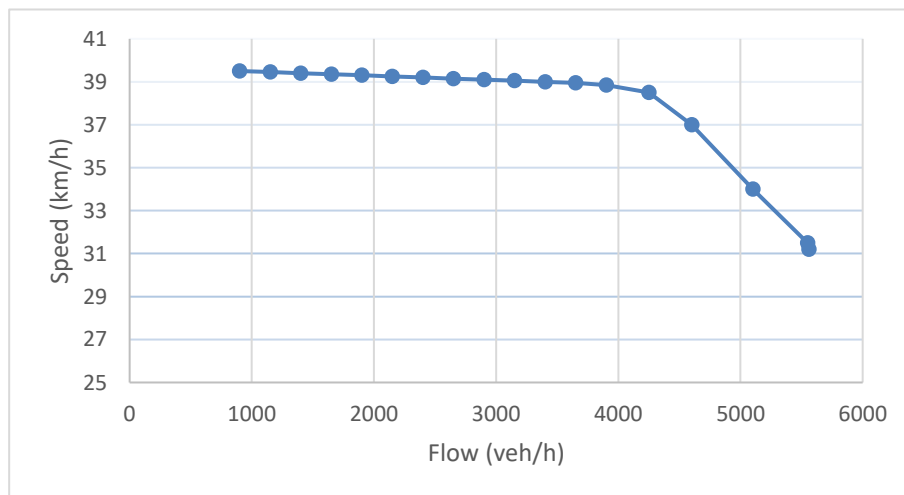


Figure 6. Speed-flow diagram for a straw speed distance scenario of 200 meters

In [Figure \(7\)](#), the flow-density diagram is plotted up to its peak, which is the maximum volume passing through, which corresponds to the maximum density factor (Kmax) of the route equal to 56.70 veh/km.

Naturally, if the demand value of the route increases, the volume passing through the route decreases towards zero and the density will reach the value (Kjam).

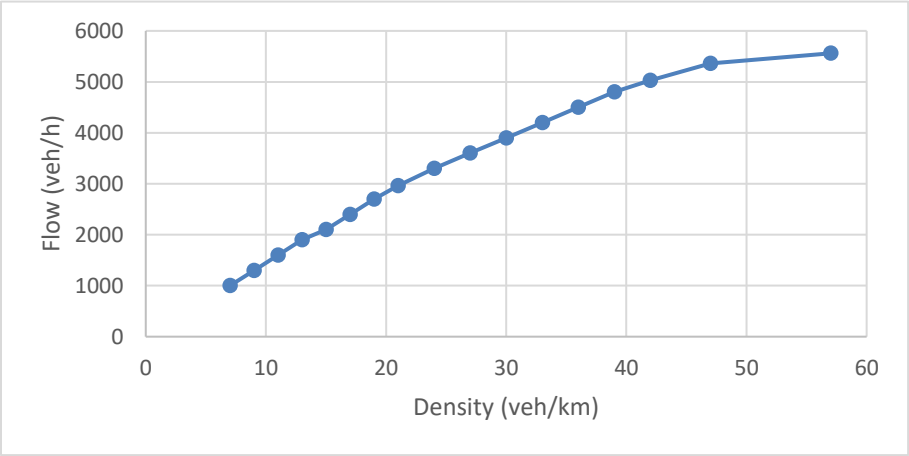


Figure 7. Flow-density diagram for the straw velocity distance scenario of 200 meters

3.3. Traffic diagrams for the 100m scenario

Important traffic diagrams are drawn for the 100m speed bump distance scenario. As shown in Figure (8), the volume passing through the model increases to 5560veh/h, which is the same as the road capacity, and then it remains constant at this value, and from this point on, only the delay time of the vehicles will

increase. This delay time in the value of the volume passing through equal to the road capacity, in the 200m speed bump distance scenario is more than in the 400m scenario and less than in the 50m and 100m scenarios.

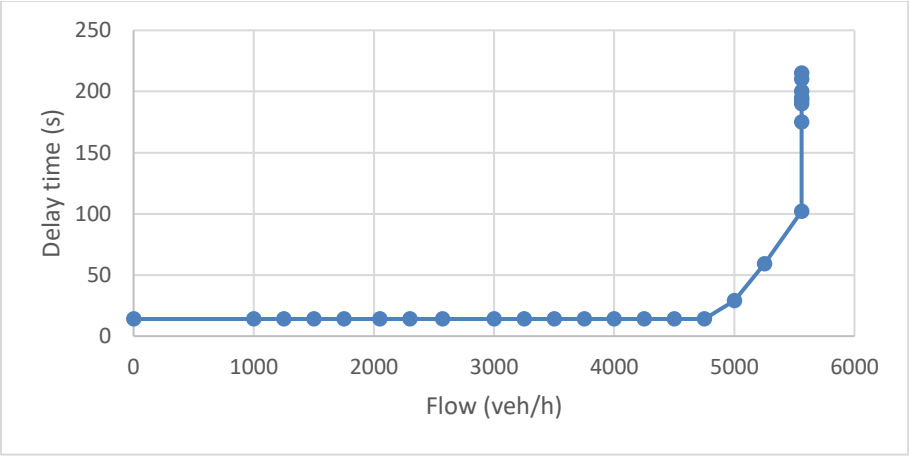


Figure 8. Time-delay-flow diagram for the straw speed distance scenario of 200 meters

The maximum flow rate for the 100-meter scenario is 5500 veh/h, as shown in Figure (9). The velocity-flow diagram is drawn to its peak, which is the

maximum volume flow rate. As demand increases in the model, the volume flow rate and vehicle speed will decrease to zero.

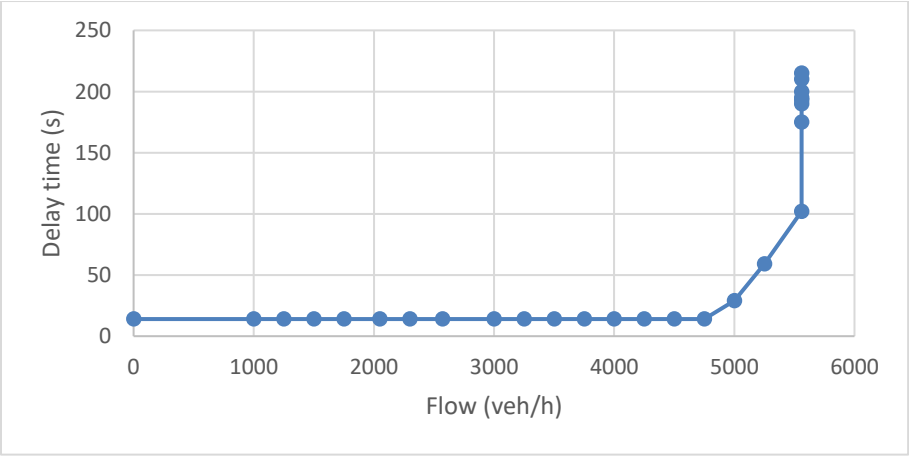


Figure 9. Velocity-flow diagram for the straw velocity distance scenario of 100 meters

As can be seen from [Figure \(10\)](#), as the model's traffic volume increases, the route density reaches its

maximum value (K_{jam}) and the speed decreases to zero.

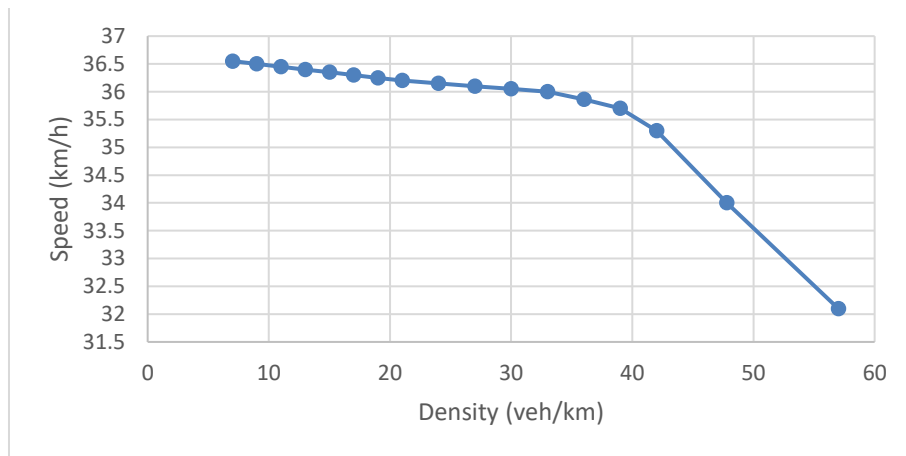


Figure 10. Velocity-density diagram for the straw speed distance scenario of 100 meters

In [Figure \(11\)](#), the flow-density diagram is plotted up to its peak, which is the maximum volume passing through, which corresponds to the maximum density factor (K_{max}) of the route equal to 04.76 veh/km.

Naturally, if the demand value of the route increases, the volume passing through the route decreases towards zero and the density will reach the value (K_{jam}).

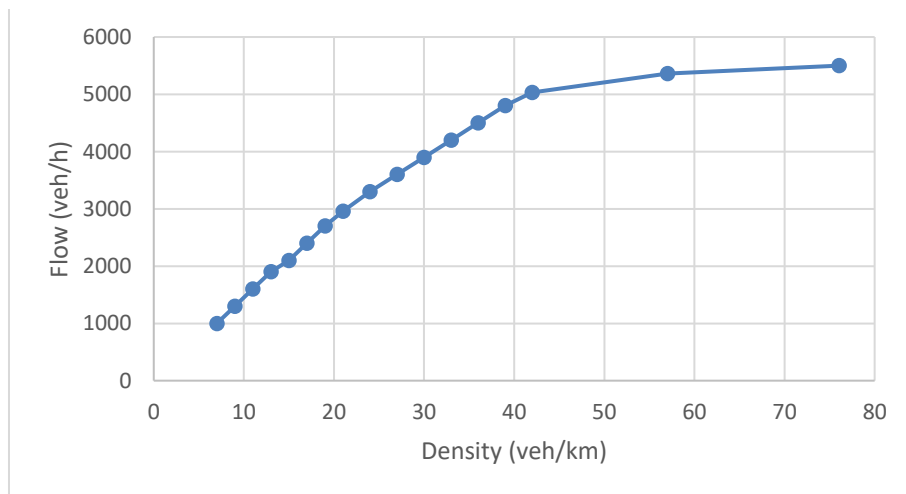


Figure 11. Flow-density diagram for the straw velocity distance scenario of 100 meters

As shown in [Figure \(12\)](#), the volume passing through the model increases to 5500veh/h, which is the same as the road capacity, and then it remains constant at this value, and from this point on, only the delay time of the vehicles will increase. This delay time in the

value of the volume passing through equal to the road capacity is more in the scenario of the speed bump distance equal to 100 meters than in the scenarios of 200 meters and 400 meters, and less than in the scenario of 50 meters.

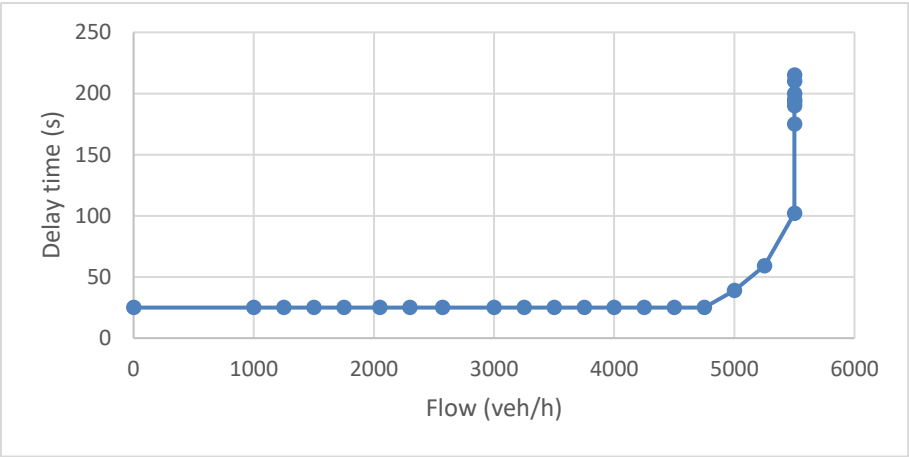


Figure 12. Time-delay-flow diagram for the straw speed distance scenario of 100 meters

3.4. Traffic diagrams for the 50-meter scenario

The last scenario defined is where the speed bumps are in the closest position to each other. Green shields diagrams and a time-delay-flow diagram are drawn for the 50-meter scenario. The maximum flow rate

for the 50-meter scenario is 5250veh/h, as shown in [Figure \(13\)](#). In this scenario, as the flow rate increases along the route, the vehicle speed will decrease more than in other scenario

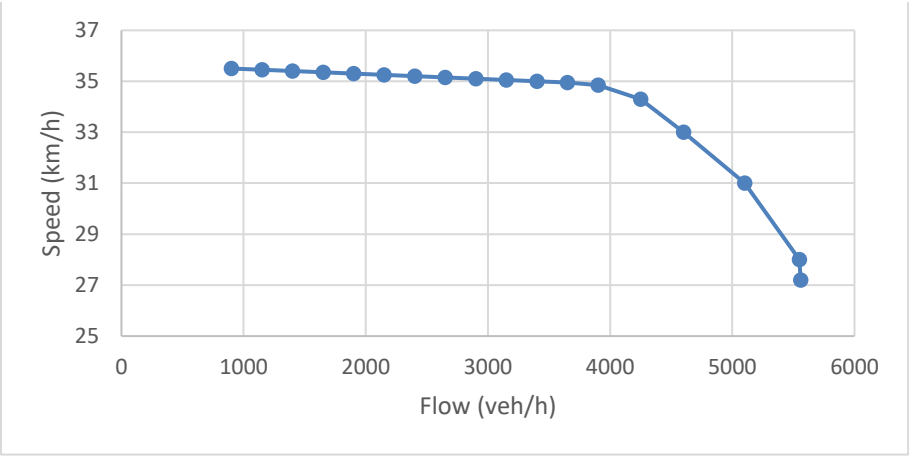


Figure 13. Velocity-flow diagram for the straw velocity distance scenario of 50 meters

As can be seen from [Figure \(14\)](#), as the model's traffic volume increases, the road density reaches its saturation value (Kjam) and the speed will decrease to zero. In the scenario where the speed bump

distance is 50 meters, this speed decrease will occur faster than in other scenarios.

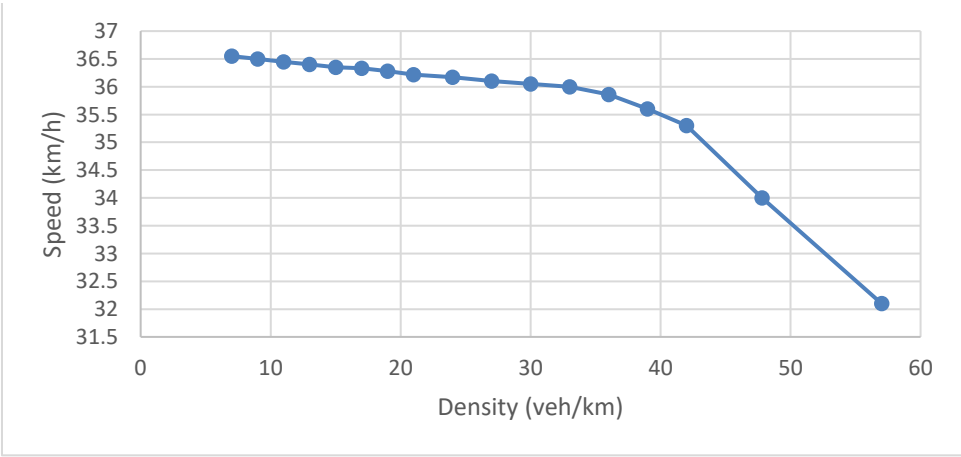


Figure 14. Velocity-density diagram for the straw speed distance scenario of 50 meters

As shown in [Figure \(15\)](#), the volume passing through the model increases to 5250veh/h, which is the same as the road capacity, and then it remains constant at this value, and from this point on, only the delay time

of the vehicles will increase. This delay time in the value of the volume passing through equal to the road capacity is more in the scenario of the speed bump distance equal to 50 meters than in other scenarios.

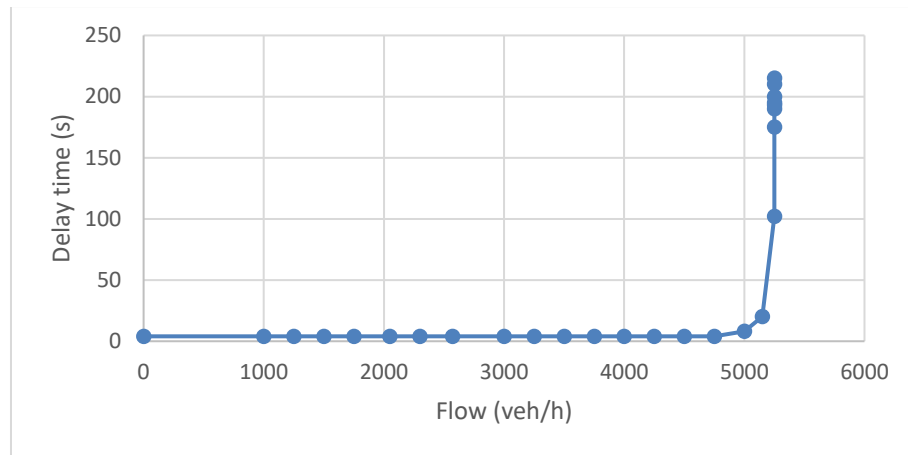


Figure 15. Time-delay-flow diagram for the straw speed distance scenario of 50 meters

[Figure 16](#) shows the flow-density diagram up to its peak, which is the maximum volume flow, which corresponds to the maximum density (K_{max}) of the route equal to 58.78 veh/km. Naturally, if the demand

value of the route increases, the volume flow through the route decreases towards zero and the density will reach the value (K_{jam}).

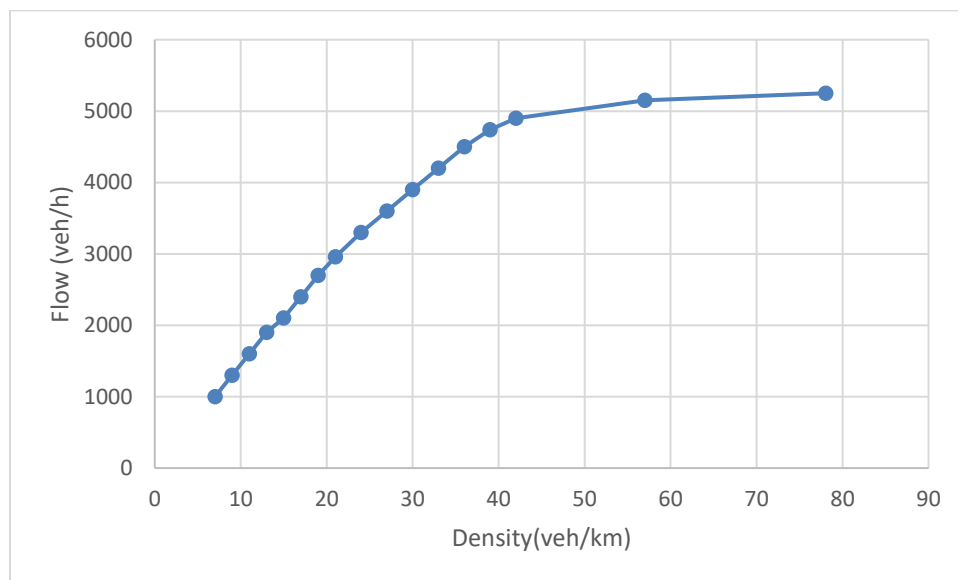


Figure 16. Flow-density diagram for the straw velocity distance scenario of 50 meters

4. CONCLUSION

The main objective of this study is to analyze the relationships between speed changes, density, flow, and delay time of a street with a traffic calming device. To achieve these goals, a field study and survey was conducted on a street located in Tehran in order to obtain real data. The street under study must have traffic calming devices so that the effect of traffic calming measures and the distance between

them can be considered. Next, the behavior of drivers is calibrated and evaluated by a model in the AIMSUN program so that it can be used for the streets of Tehran. Then, the relationship diagrams between variables such as speed, density, flow, and delay time are drawn and examined. Among the important results of this study are:

- The greater the flow volume, the lower the speed, but if, in the current conditions, we reduce the distance between the speeds bumps, we reach the maximum flow volume at a lower speed.
- As density increases, the speed of vehicles decreases. Now, in the present situation, if we reduce the distance between the speed bumps, we reach the maximum density at a lower speed.
- As the density increases, the flow volume also increases, but if we reduce the distance between the speed bumps, the slope of the graph becomes smaller and we reach the maximum flow volume at a lower density.
- As long as the flow volume has not reached its capacity limit, the delay time remains constant, but when it reaches capacity, the delay time increases very sharply. In this situation, if we reduce the distance between the speed bumps, the flow capacity limit decreases.
- The capacity obtained from the simulated models for the street without speed bumps is 2160 veh/h/ln, and for the speed bump distance of 400 meters, it is 1870 veh/h/ln, for the 200-meter distance, it is 1850 veh/h/ln, for the 100-meter distance, it is 1840 veh/h/ln, and for the 50-meter distance, it is 1760 veh/h/ln. The service level of each scenario, considering the average speed of the vehicles, is as follows: at a distance of 400 meters and 200 meters, the street service level is C, and at a distance of 100 meters, service level D is provided, but at a distance of 50 meters, which is a critical distance, the undesirable service level E is provided.
- The maximum flow (Q_{max}) was obtained for various scenarios, which is 5590 veh/h at a speed bump distance of 400 meters, 5560 veh/h at a speed bump distance of 200 meters, 5500 veh/h at a speed bump distance of 100 meters, and 5250 veh/h at a speed bump distance of 50 meters.

FUNDING/SUPPORT

Not mentioned any Funding/Support by authors.

ACKNOWLEDGMENT

Not mentioned by authors.

AUTHORS CONTRIBUTION

This work was carried out in collaboration among all authors.

CONFLICT OF INTEREST

The author (s) declared no potential conflicts of interests with respect to the authorship and/or publication of this paper.

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